Smart Structures and Systems

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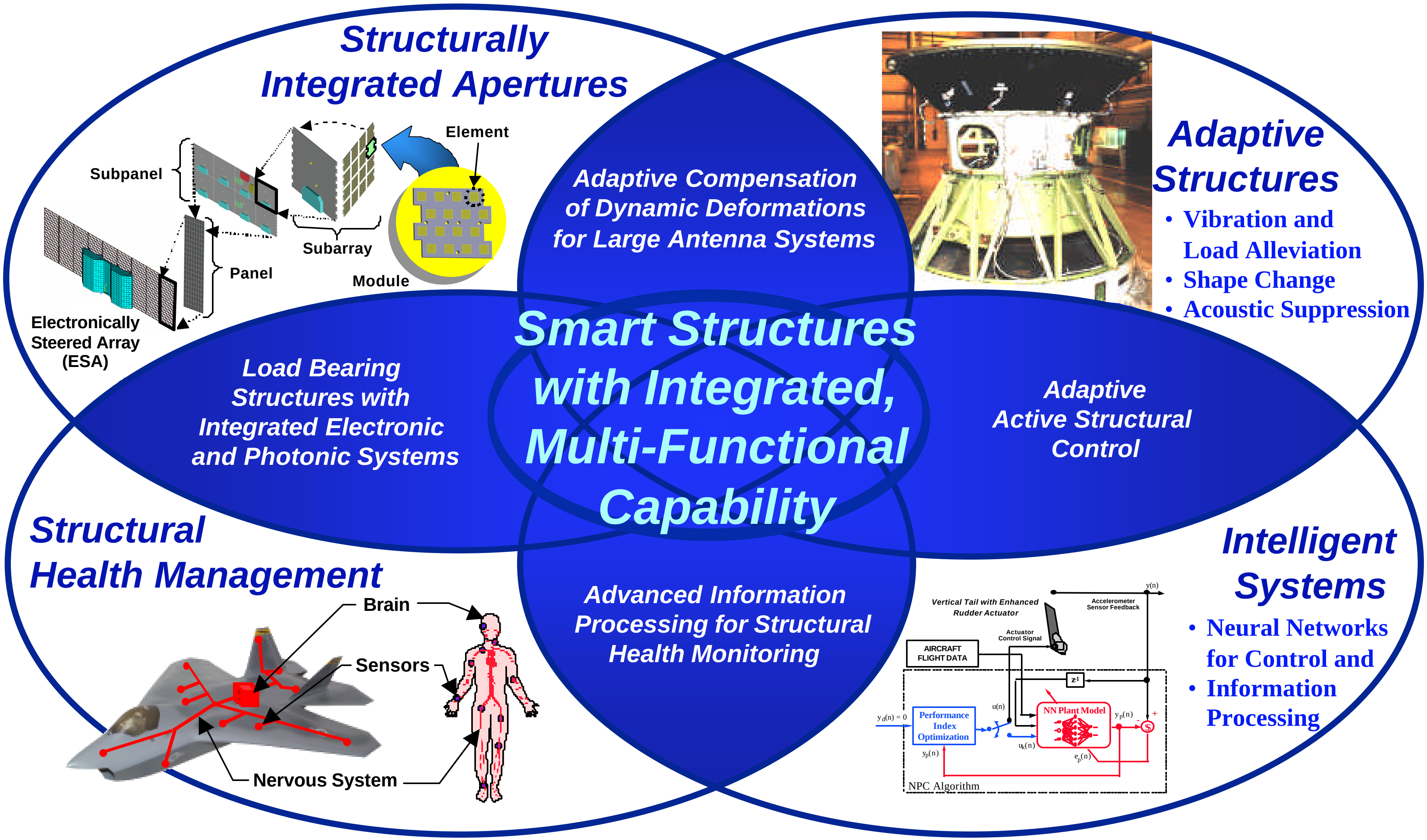
Smart Structures Focus Areas



Technology Transition Strategy

S A M P S O N

Technology Readiness Level (TRL)

2004-7	System Implementation	System Test, Flight and Operations	9	Actual system "Flight Proven" through successful mission operations
			8	Actual system completed and "Flight Qualified" through test and demonstration
2002	Flight and At-Sea Demonstrations	System/Subsystem Development	7	System prototype demonstrated in operational environment
2000	SAMPSON	Technology Demonstration	6	System/subsystem model or prototype
			5	Component and/or breadboard validation in a relevant environment
1997	SPICES	Technology Development	4	Component and/or breadboard validation in a laboratory environment
		Research to Prove Feasibility	3	Analytical and experimental critical function and/or characteristic proof-of-concept
			2	Technology concept and/or application formulated
1993		Basic Technology Research	1	Basic principles observed and reported

Synthesis and Processing of Intelligent Cost Effective Structures

Develop Cost Effective Material Processing and Synthesis Technologies Which Will Enable New Products Requiring Active Vibration Suppression and Control Systems to be Brought to Market

Actuator Development
- High Force PZT Systems
- New forms of Shape Memory Alloys
- Survivable Subsystems

Heterogeneous Modeling
- Superelement Techniques
- Interfaces to Control Design
- Nonlinear Capabilities

Manufacturing/Integration
- Embedding Techniques
- Automated Fabrication
- Advanced Nervous Systems

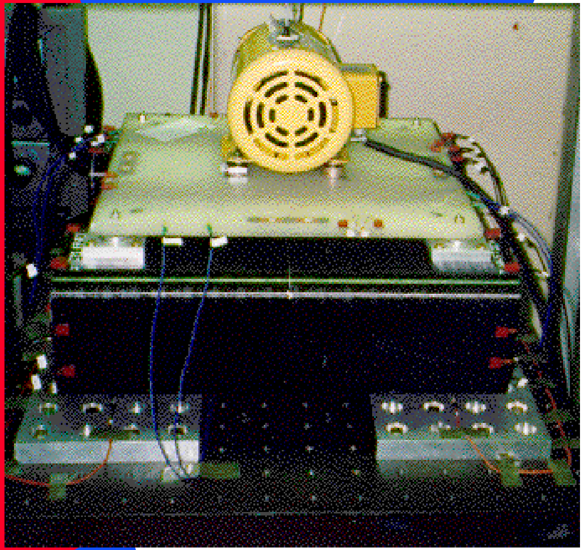
Hierarchic Control Systems
- Local Damping Augmentation
- Global Vibration Control
- Electrical Shunting
- Frequency Shifting

Sensor Development
- Fiber Optics
- Piezo sensors
- Microaccelerometers

Active Mount Concept

1-4 KHz Vibration Control (Commercial Application)

5-100 Hz Vibration Control (Military Application)



Final Fabrication and Demonstrations
- Demonstrate 30dB attenuation
- Quantification of Best Practices and Cost Effective Procedures

SPICES II Applications Screening Process

Identified Candidate Applications {
- ~ 200 for Fixed Wing Aircraft
- 61 for Engines (49 Fighter/12 Transport)
- 16 for Underwater Vehicles (10 Sub/6 Torpedo, UUV)

Mission Improvements → Component Identification → Enhancement Definition → Smart Structure Concept Defined → Ranking Based on Payoff, Risk, Time to Deploy → Sort to Identify Common Technologies

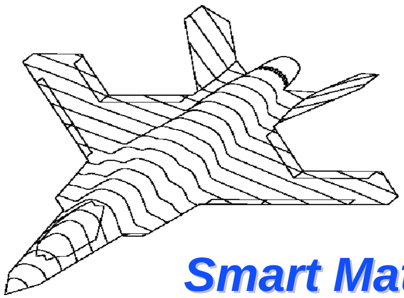
Concepts Were Quantitatively Screened and Down-selected to:

- 3 Fixed Wing Aircraft
- 4 Marine
- 4 Gas Turbine Engine (2 Tactical, 2 Transport)

Downselected Aircraft Smart Materials Concepts

SPICES PHASE II

Downselected Concepts	High Performance Platforms	Details	Core Technologies
Control Surface Shape Change - Quasi-static	Supersonic Covert Penetrator, Unmanned Tactical Aircraft, Missiles, Munitons	Low Rate, Smooth Surface Deflection of LE & TE Flaps	SMA & Flex Skin
Inlet Shape Change	Light Weight Strike Fighter, Supersonic Covert Penetrator	Capture Area Control, Ramp Angle Change, Lip Blunting	SMA & Flex Skin
Door and Control Surface Gap Filling	Supersonic Covert Penetrator, Unmanned Tactical Aircraft	Close Gap Between Deflected Flap and Wing Trailing Edge	Flex Skin
Wing Lift Increase	Military Aircraft, Fighter and Transport,e.g., Blended Wing-Body	Replace Leading Edge Slats with Shape Change	SMA & Flex Skin
Control Surface Shape Change - High Rate	Unmanned Tactical Aircraft	Actual or Virtual Shaping of Flaps, Ailerons, Rudders	Inchworms & Flex Skin, Synthetic Jets
Inlet Approach Surface Boundary Layer Control	Blended Wing-Body	Energize Boundary Layer over Wing/Fuselage Surface	Synthetic Jets
Control Surface Boundary Layer Management	Supersonic Covert Penetrator	Energize Boundary Layer over Deflected Flaps and Ailerons	Synthetic Jets
Inlet Diffuser Boundary Layer Management	Fighter Aircraft, Supersonic Covert Penetrator	Energize Boundary Layer Inside High Offset Inlet Duct	Synthetic Jets
Nozzle Fluidics Thrust Vectoring	Supersonic Covert Penetrator	Achieve High-Rate Jet Flow Turning and Area Control	Synthetic Jets
Wing & Tail Shaping for Maneuvering Enhancement	Advanced Cruise Missile, Advanced Munitions	High-Rate Surface Shape Change for Maneuvering	Piezo Sheets, Stacks, Inchworms
Moldline Control in Maneuvering Flight	Unmanned Tactical Aircraft	Maneuverability Without Deflecting Control Surfaces	Synthetic Jets
Weapons Bay Noise/Wake Control	Supersonic Covert Penetrator, Strategic Supersonic Bomber	Active Cancellation of Cavity Acoustics	Synthetic Jets
Wing Drag Reduction	Supersonic Covert Penetrator	Adjustable Wing Camber	Synthetic Jets
Nozzle Area Control	Supersonic Covert Penetrator	Control Jet Area Inside Fixed-Aperture Nozzle	High Temperature SMA



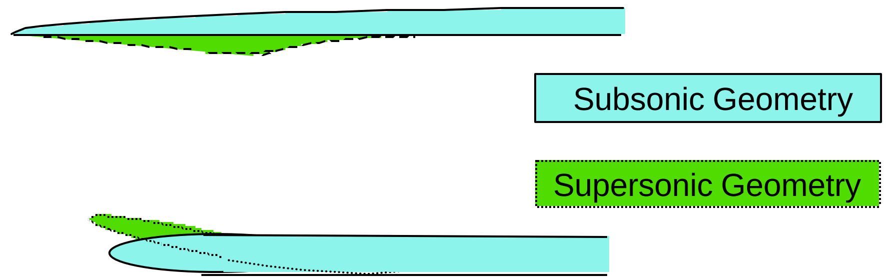
New Mission Is Enabled by Variable Geometry Smart Structures Inlet

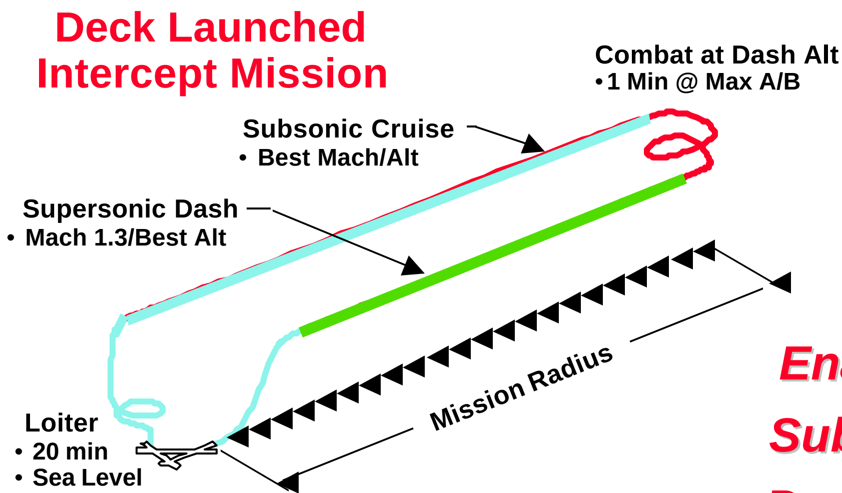
Smart Materials Actuated Variable Geometry Inlet Provides:

Compression Ramp

Capture Area Control

Lip Blunting





Variable Geometry Inlet Provides

20%+ Increase in Mission Radius

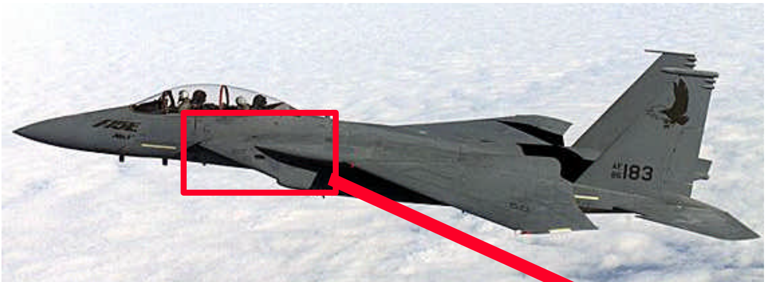
(relative to fixed inlet baseline design)

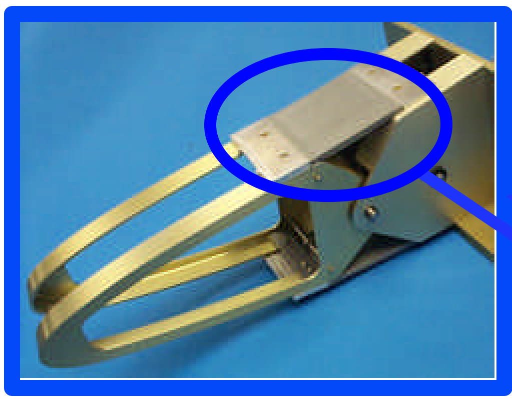
Enables Strike Aircraft Optimized for Subsonic Interdiction Mission to Also Perform Supersonic Intercept Mission

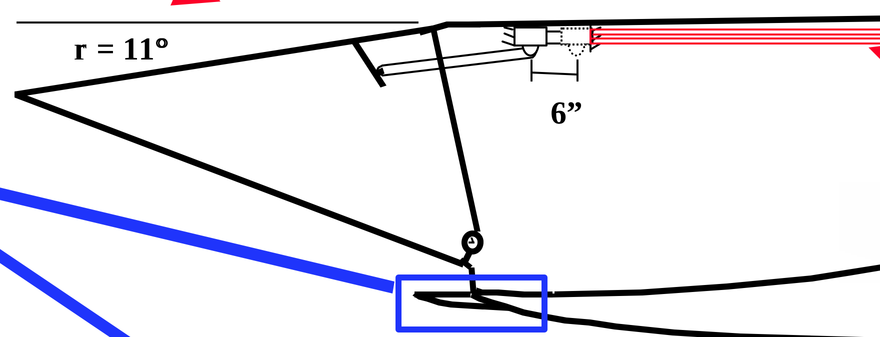
SAMPSON Modified F-15 Inlet with Smart Structures Actuation

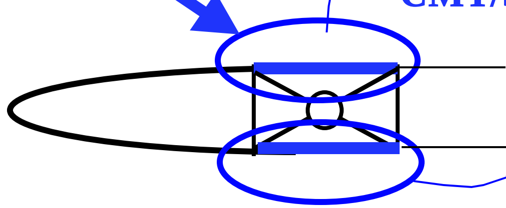
- *First <u>full-scale</u> demonstration of high force & displacement smart materials actuation.*
- *First integration of SMA* rod actuators within compliant structure configurations.*
- *First applications demo of Pd doped SMA (high transition temperature)*

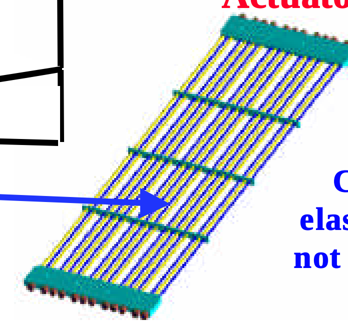
<u>First entry in Langley 16-Ft Transonic April 2000</u>











Adaptive inlet provides >20% increase in mission radius re: fixed geometry inlet (F-16, F/A-18)

** SMA = Shape Memory Alloy,*
CMT = Conformal Moldline Technology
SAMPSON = Smart Aircraft and Marine Projects Demonstration

Technology Readiness Levels

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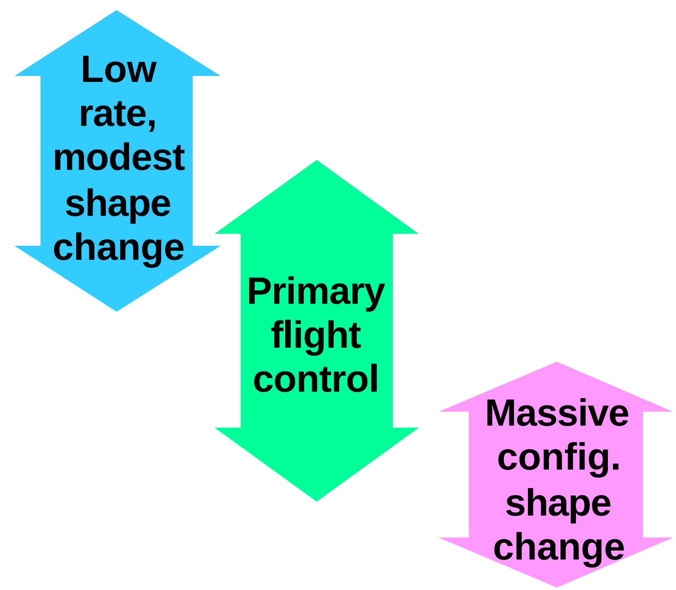

Technology Readiness Levels Required to be Ready for Flight Test

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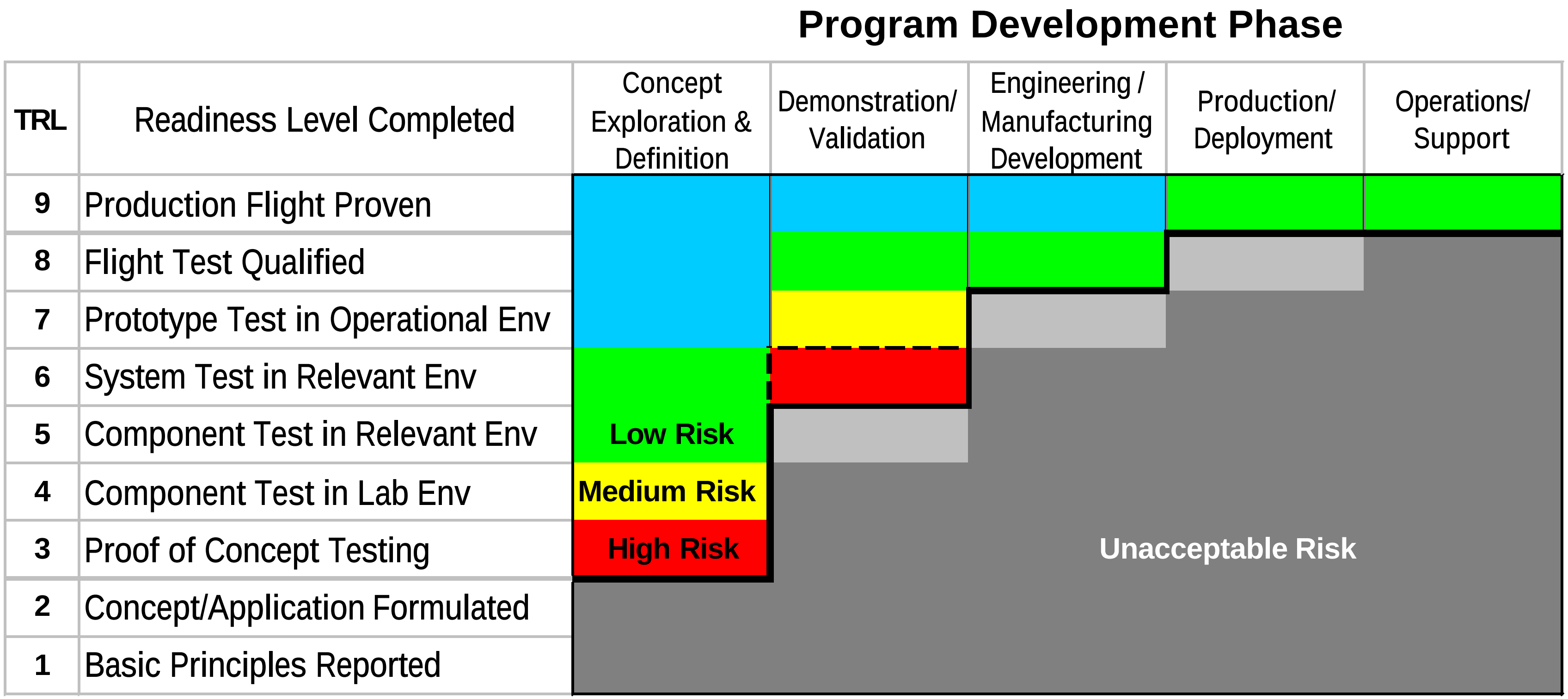
TRL 7 min. for SOF critical appl. ready for full scale flight test

TRL 6 min. for SOF critical appl. ready for sub-scale flight test, or Non-SOF critical applications ready for full scale flight test

TRL 5 min. for Non-SOF critical applications ready for sub-scale flight test

SOF = Safety of Flight

Acceptable Technology Risk Level Varies with Program Maturity



Typical Program Lower Limit on Risk

May be Acceptable to Solve a Problem

May Not Be Actively Tracked Under Risk Management

Transition Conclusions

- Smart structures transition requires high TRL if transition is during or after E&MD
  - Risk (real and perceived)
  - Impact to re-qualification
  - Impact to operations and support

  All conspire to overwhelm benefits and kill the business case
  (unless it solves a problem)

- Need to enable paradigm shift, but MUST have a viable mission
  - Entirely new mission
  - Multi-mission - replace two or more systems
- Suggested approach
  - Clean sheet design
  - UAV to reduce acceptable risk and program cost
  - Phased approach to provide intermediate, nearer term capability
    (low rate, modest shape change first, then massive shape change and primary flight control)

Smart Structures UAV Mission

- Long duration UAV with high speed capability
  - ISR capabilities - E/O, SAR / large ESA
  - High Speed for Deploy / Retasking (>M=0.7, >M=1?)
  - Attack capability on Mobile / Relocatable Targets
  - High Altitude (trades for survivability)
- Wing shape change - span, AR, sweep, area
  - Low Rate shape change is nearer term enabler
  - Massive shape change should be product improvement
  - Primary flight control benefits are secondary
- Demo on no smaller than half scale

Global Hawk ISR Capability

Attack Capability

Smart Structures UAV

High/Low speed flight capability